Distr.
LIMITED

A/CONF.184/BP/6
26 May 1998

ORIGINAL: ENGLISH

THIRD UNITED NATIONS CONFERENCE
ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE

BASIC SPACE SCIENCE AND MICROGRAVITY RESEARCH AND THEIR BENEFITS

Background paper 6

The full list of the background papers:

1. The Earth and its environment in space
2. Disaster prediction, warning and mitigation
3. Management of Earth resources
4. Satellite navigation and location systems
5. Space communications and applications
6. Basic space science and microgravity research and their benefits
7. Commercial aspects of space exploration, including spin-off benefits
8. Information systems for research and applications
9. Small satellite missions
10. Education and training in space science and technology
11. Economic and societal benefits
12. Promotion of international cooperation

V.98-53856 (E)

CONTENTS

		Paragraphs	*Page*
PREFACE			3
SUMMARY			4
I.	RATIONALE	1-9	4
II.	PRACTICAL BENEFITS OF SPACE SCIENCE AND PLANETARY EXPLORATION	10	6
III.	MOTIVATING EDUCATION AND SCIENTIFIC LITERACY	11-15	6
IV.	CREATING A FOCUS FOR SPACE SCIENCE	16-17	7
V.	INTERNATIONAL AND REGIONAL BASIC SPACE SCIENCE WORKSHOPS.	18-22	8
VI.	THE ROLE OF NON-GOVERNMENTAL ORGANIZATIONS AS A CATALYST	23	9
VII.	EDUCATIONAL MATERIALS AND CURRICULA	24-25	9
VIII.	SPECIFIC PROJECTS AND TECHNICAL CONTRIBUTIONS	26-29	10
IX.	MICROGRAVITY RESEARCH AND THE INTERNATIONAL SPACE STATION	30-38	11
X.	APPRAISAL	39-40	12

PREFACE

The General Assembly, in its resolution 52/56, agreed that the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) should be convened at the United Nations Office at Vienna from 19 to 30 July 1999 as a special session of the Committee on the Peaceful Uses of Outer Space, open to all Member States of the United Nations.

The primary objectives of UNISPACE III will be:

(a) To promote effective means of using space technology to assist in the solution of problems of regional or global significance;

(b) To strengthen the capabilities of Member States, in particular developing countries, to use the applications of space research for economic and cultural development.

Other objectives of UNISPACE III will be as follows:

(a) To provide developing countries with opportunities to define their needs for space applications for development purposes;

(b) To consider ways of expediting the use of space applications by Member States to promote sustainable development;

(c) To address the various issues related to education, training and technical assistance in space science and technology;

(d) To provide a valuable forum for a critical evaluation of space activities and to increase awareness among the general public regarding the benefits of space technology;

(e) To strengthen international cooperation in the development and use of space technology and its applications.

As one of the preparatory activities for UNISPACE III, the Office for Outer Space Affairs of the Secretariat has prepared a number of background papers to provide Member States participating in the Conference, as well as in the regional preparatory meetings, with information on the latest status and trends in the use of space-related technologies. The papers have been prepared on the basis of input provided by international organizations, space agencies and experts from all over the world. A set of 12 complementary background papers have been published and should be read collectively.

Member States, international organizations and space industries planning to attend UNISPACE III should consider the contents of the present paper, particularly in deciding on the composition of their delegation and in formulating contributions to the work of the Conference.

The present paper was prepared with the assistance of teams of experts from the European Space Agency (ESA) the Centre national d'études spatiales (CNES) of France, the Indian Institute for Astrophysics (IIA) the Indian Space Research Organization (ISRO), the International Space University (ISU), France, the Harvard-Smithsonian Center for Astrophysics (CFA), United States of America, the National Aeronautics and Space Administration (NASA), United States of America, The Planetary Society (TPS) United States of America, the United Nations Office at Vienna and the University of Science Malaysia (USM).

The assistance of M. J. Rycroft (International Space University, Strasbourg, France, and Cambridge University, United Kingdom of Great Britain and Northern Ireland) as technical editor of background papers 1 to 10 (A/CONF.184/BP/1-10) is gratefully acknowledged.

SUMMARY

The exploration of the universe from our solar system to the most remote parts represents one of the greatest intellectual adventures of humankind. The past four decades have witnessed a dramatic change in our views about the universe and its constituent parts, an ongoing revolution whose implications are still to be fully understood not only in the scientific context but also from a practical point of view. Such a widening of our horizons in such a short time is unprecedented in human history, with the possible exception of the time of Galileo. The great advance made by Galileo resulted from his use of a new optical device, the telescope, a huge step forward in the technology of his time. In a similar way the advances in technology characteristic of modern times have provided the basis for the discovery of completely new sets of phenomena that have radically modified our understanding of problems such as the formation and evolution of planets, stars, galaxies and the universe as a whole.

Images of the Earth taken from space and satellite studies of the global Earth system and global change have created a dramatically new perspective on the relationship between the inhabitants of Earth and their planet. Continuing studies of that relationship will improve understanding of how human activities may be affecting the health of the global environment.

Through telescopic images and robotic space probes, further details about the nine planets in the solar system, as well as its numerous moons, asteroids and comets, have become known. It has been discovered that many features of planet Earth are shared by other bodies of the solar system and thus the unique features of Earth that make possible its great diversity of life may be better appreciated.

The beginnings of the space age came at a crucial time in human history. For the first time humans now have the ability to alter the entire planet for better or for worse. The perspectives gained from space help us to understand the challenges facing civilization. Space age technologies in space exploration, remote sensing, communications and meteorology transcend economic and cultural borders. No longer can nations, or people, live in isolation. They must come together in education and global cooperation.

I. RATIONALE

1. Ever since humans learned to walk upright, they have looked at the sky and wondered. The sky has remained the same but not its meaning. At first it was thought of as a divinity to be feared and appeared, then as a phenomenon to be observed and utilized, and finally as a laboratory for studying nature. Through those stages, over the millennia, outer space has acquired a depth that mirrors the changing patterns of humankind's relationship with its cosmic environment.

2. Because of the spherical nature and rotation of the Earth, no country or observatory, no matter how well equipped, can observe the whole of the celestial sphere at all times. Also, cosmic phenomena can only be observed; adjustments cannot be made, nor can repeated observations of the same situation be obtained. Consequently, basic space science, unlike most laboratory science, is additive rather than exclusive, complementary rather than competitive. Although large-scale facilities, including space missions, must necessarily depend upon the initiative of highly industrialized countries, there is ample scope for regional and international collaboration and cooperation. Scientific instrumentation, engineering subsystems and data analysis are some of the areas where countries, observatories and academic groups can make valuable contributions. There is now a genuine desire and need for

international pooling of resources and ideas. Additionally, military technology and expenditure are being redirected towards basic space science.

3. Scientific inquiry into the nature of the universe beyond the Earth and exploration of the Sun's planetary system have, to date, been enterprises carried out by only a few countries. Perhaps for that reason, their relevance to the issues that are the focus of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) have not yet been given adequate attention or priority.

4. Clearly, the space science and exploration achievements of the last several years have captured the world's attention, interest and imagination. The people of Earth have shared the excitement of discovering and exploring the new worlds of our solar system and of looking beyond it into the cosmos. This era may prove to be as epochal as was the period of exploring the new worlds on Earth half a millennium ago.

5. Perhaps the primary benefits of this new age of discovery are in their impact on humanity's appreciation of its own global habitat in the context of the solar system and the universe beyond. The recognition that human beings are not at the centre of the universe but are part of a greater natural order represented a dramatic change in the attitude of people towards the world around them.

6. The new appreciation for the interdependence of human beings and their natural environment has inspired a vast expansion of interest in and study of the natural environment, including other planets, stars and the universe as a whole. In addition, the benefits of scientific discovery are quite tangible. Basic space science is a key to the prosperity of a nation and it is almost impossible to expect a country to have significant economic and social development without a sound educational and research base in the field of basic space science.

7. In the 40 years of the space age, scores of new worlds have been transformed from barely discernible points of light to whole new places of wonder. There is some evidence for past life on Mars, from indirect evidence showing it to have been warmer and wetter and, maybe, from direct evidence in meteorites that were catapulted off the planet and landed here on Earth millenniums later. The moons of Jupiter are far more dynamic than previously thought; Europa probably has an ocean of liquid water continually being heated by tidal forces; Ganymede has a magnetosphere; and Io is characterized by continuous volcanic activity. Venus has a surface hot enough to melt lead, while sulphuric acid and aerosols make its atmosphere equally inhospitable. Comets and asteroids bombard the planets. Not only have such collisions been observed first-hand (for instance, Shoemaker-Levy 9's impact with Jupiter): these bodies have also been approached close up to see their composition and bizarre topography. Now it is known that 65 million years ago the evolution of life on Earth suffered a catastrophic change as a result of the impact of an asteroid or comet.

8. In addition, the people on Earth have been privy to stunning observations of galaxies colliding or being born at the edge of the universe, new evidence for the existence of black holes and discoveries of planets orbiting other stars. The broad interest in such recent discoveries should not be surprising. The nature of life in the universe intrigues everyone, both rich and poor, in both industrialized and developing areas. Throughout human history, in all human cultures, people have wondered about their place in the cosmos, the nature of planets and stars and their relations to Earth, whether they are alone and the evolution of the universe, galaxies, stars, planets and of man himself. They have done this in their folklore, mythology, religion and culture, and now they can do it through science. Happily, that science is a complex and far-reaching task. The search for life in the universe (and indeed all aspects of planetary exploration and space science) require broad and multidisciplinary approaches: there is room for all. Through widespread communication, instant availability of data and information, and the interest of all—especially children—in exploration, space science and planetary exploration are becoming worldwide participatory activities, not just elitist ones.

9. Space science and exploration truly reflect the popular *raison d'être* for space programmes. Previous UNISPACE conferences placed emphasis on space science and exploration and this will be again a focal point in

UNISPACE III. While portions of the agenda properly focus on tangible space benefits for humanity that can flow from the application of space technologies and capabilities, it also gives attention to that part of space activity that engages the interest of a great number of people around the world.

II. PRACTICAL BENEFITS OF SPACE SCIENCE AND PLANETARY EXPLORATION

10. The discoveries cited above, and many others, have given birth to new understandings in many sciences: physics, astronomy, geology, biology and the environmental, ecological, engineering and computer sciences, for example. In addition to the intellectual benefits of new knowledge, however, many significant, mundane and specifically practical benefits have also had considerable effects on mankind:

(a) The "runaway" greenhouse effect on Venus, caused by an excess of carbon dioxide in its atmosphere, has led to an understanding of the dangers of carbon dioxide build-up on Earth and the resulting global climate change;

(b) The antiseptic surface of Mars, clean of any life or organic material because there is no ozone layer to protect it, provides a bleak description of what might happen if Earth's ozone layer were destroyed;

(c) Finding aerosols in the atmosphere of Venus and observing how they interact with the molecules there has led to knowledge about what happens when aerosols are introduced into Earth's atmosphere;

(d) Observing and analysing the dust storms on Mars have provided scientists with models of what happens to a planet's climate if massive amounts of dust are blown into the atmosphere, as would happen on Earth from a volcano or from the large impact of an extraterrestrial object;

(e) Asteroid and comet impacts on the terrestrial planets have profoundly influenced their evolution and it is now known that on Earth such impacts have wiped out species such as dinosaurs in the past and could do so again in the future.

All these observations have significance for all peoples of the Earth.

III. MOTIVATING EDUCATION AND SCIENTIFIC LITERACY

11. In towns and villages anywhere on Earth, youngsters show an interest in the stars and planets. Discussion of them in a classroom motivates learning, especially in modern sciences and mathematics. Astronomy has long been a pace-setter in motivation and in applications for education and the development of scientific literacy. Ever since Galileo wrote *The Starry Messenger*, astronomy has been a means of communicating science and mathematics to the public and a motivator for children to learn those subjects. In the twenty-first century world of information and technology, broad understanding of science, mathematics and technical subjects is crucial if people are to improve their quality of life. Through the World Wide Web, other Internet services, the public media, satellite television, educational and motivational programmes and telerobotics, the findings of space science and planetary exploration will be available to all. They can catalyse learning. To assume that modern space science and planetary exploration are not relevant to a poor or illiterate population only ensures that they will remain so.

12. Scientific illiteracy is one of the world's greatest problems and an increasingly divisive factor between haves and have-nots. Increase in the quality of life and economic growth now depend to a large extent on scientific and technical awareness and on the ability to incorporate new knowledge and devices into the economics of societies and the lives of individuals. While learning about Jupiter's atmosphere does not necessarily contribute to income-generation or solve economic problems, learning about the exploration of Jupiter is an integral part of a whole educational experience, motivating students and teachers to understand the global environment better. Dealing with

the brain drain is a major challenge in many countries: young people are turning away from creative enterprises of high achievement because of lack of opportunities. Some bright young people interested in science and technology may go to major industrialized countries to seek opportunities, but others are discouraged by the lack of opportunities and follow less productive paths because of higher financial incentives. In the past, weapons technology was an area of opportunity for creative engineering in the United States of America and countries of the former Union of Socialist Soviet Republics. The end of the cold war is now fortunately reducing the demand for new weapons, but the need for creative outlets for the human imagination remains and the opportunity for it to be exercised peacefully is now greater. Space work is not the only opportunity, but it is one of the best and certainly one of the most motivating.

13. The technology of exploration is crucial in this respect. Communications, remote sensing, miniaturization, propulsion, electronics, information processing and navigation are developments needed in all countries. Of course, these and other technologies and engineering skills will be developed in far more widespread applications than in space science alone, but the power of space science in the educational system to motivate the learning of such skills cannot be overestimated. The distinguishing feature of space science is the means by which it advances exploration. This captures public interest and provides a vision like little else in modern science and technology.

14. Large rockets are required to get to the planets, which is why only a few nations have conducted planetary missions. However, participation in the missions through scientific instruments, interdisciplinary investigations, education and public information programmes, engineering subsystems, high-technology manufacturing and innovation can all be done on a small scale as well as a large one. One or two scientists or a university group can make a substantive contribution, bringing credit to and interest throughout a whole country. Of perhaps greater potential is the redirection of military technology and expenditure to civilian space applications, employing the same technical disciplines, applied to a problem of even greater motivation: the exploration of the universe.

15. Basic scientific exploration has invariably been a catalyst for the development of a variety of new technologies. Space technology is no exception, driven as it is by the exacting requirements of space science and astronomical experiments requiring very accurate pointing mechanisms, better attitude-control systems and a variety of highly sensitive sensors. It is widely recognized that today's science is tomorrow's technology and that any nation that wants to advance technologically cannot afford to ignore investments in space science.

IV. CREATING A FOCUS FOR SPACE SCIENCE

16. The United Nations, and specifically its Committee on the Peaceful Uses of Outer Space and Office for Outer Space Affairs, could take the lead in involving both the scientific communities and the general public of developing countries in space science and planetary exploration. These bodies are the only institutions in which representatives of "space-faring" and developing countries meet on a regular basis and thus have a natural role in this area, once a decision to give the subject added emphasis is taken. In addition, these bodies already concern themselves with making sure that the tangible benefits of space research are made available to the developing world; extending this focus as proposed in the present paper is quite consistent with that concern. In fact, the United Nations has already taken important steps in that direction, most notably by convening a series of workshops on basic space science around the world.

17. However, there is more that might be done, as is outlined below. In addition to its emphasis on space applications, the United Nations could develop information and training programmes based on the results and activities of space science and planetary exploration for those in developing countries wishing to increase their scientific literacy. Workshops or symposia assisting scientists in responding to announcements of opportunities to participate in space missions and for educators and others interested in the broader issues of space science and planetary exploration could be convened under United Nations auspices. In addition, the United Nations could create a clearing-house for both print and electronic information at various technical levels using contributed funds to translate such material into various languages and to create a World Wide Web site for the

dissemination of information.

V. INTERNATIONAL AND REGIONAL BASIC SPACE SCIENCE WORKSHOPS

18. In 1991, the United Nations held its first basic space science workshop in India for Asia and the Pacific as a follow-up to the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), held at Vienna from 9 to 21 August 1982. During that Conference the need to organize workshops and conferences in space science for developing countries was identified. The Office for Outer Space Affairs therefore developed the basic space science workshop programme for the period 1990-2000. The aim of the basic space science workshops was to help in bridging the gap in space science knowledge between industrialized and developing countries. Later in 1991 the first Space Conference of the Americas was held in San José, co-hosted by Costa Rica and Colombia, to stimulate collaboration in space science and space exploration among the Americas. The theme of the workshop included, in the first week, the solar system, planets, small bodies and planetary missions at San José and, in the second week, astrophysics, radio astronomy and cosmology in Bogotá. During the educational session of the Conference, interest was expressed by many countries of the region in workshops on space science. The Planetary Society (TPS), the United Nations and the European Space Agency (ESA) were represented at the Conference and jointly decided to organize basic space science workshops for the region.

19. Since then, workshops have been held almost yearly in different regions around the world, always concentrating on the needs of developing countries in space science. Workshops were held in 1991 in India for Asia and the Pacific, in 1992 in Costa Rica and Colombia for Latin America and the Caribbean, in 1993 in Nigeria for Africa, in 1994 in Egypt for western Asia, in 1996 in Sri Lanka for Asia and the Pacific, in 1996 in Germany for Europe and in 1997 in Honduras for Latin America and the Caribbean. The specific theme and focus of each workshop were defined by the host country taking into account the interests of the region, but the common theme was space science and scientific collaboration. During the workshops special attention was given to identifying areas of greater interest in space science as well as means to facilitate scientific collaboration. The workshops consisted of a combination of scientific presentations as well as working group sessions aimed at identifying the needs of the region with respect to mechanisms for cooperation in space science. The findings of each workshop were published in United Nations reports and in publications by the principal organizational sponsors.

20. In the report of the Sixth United Nations/European Space Agency Workshop on Basic Space Science, held at Bonn from 9 to 13 September 1996, it is stated (A/AC.105/657, para. 26):

> "The participants strongly recommended that the United Nations should exert its best efforts to ensure that the ... workshops on basic space science continue in the years to come ... such that the benefits ... are optimally oriented toward young scientists in the various geographical regions."

21. Besides the benefits to the region, there are additional benefits to the space science community from such interactions. TPS and ESA brought high-level scientists to the workshops who returned with new ideas and vitality in their work. (The participation of personnel of the Austrian Space Agency (ASA), the Centre national d'études spatiales (CNES) of France, the German Space Agency (DARA), the International Astronomical Union (IAU), the Institute of Space and Astronautical Sciences (ISAS) of Japan and the National Astronautical and Space Administration (NASA) of the United States of America, is also acknowledged.) The individuals involved have cited those benefits as the reason for their willingness to take time off at no pay to continue to provide workshop faculty and expert support.

22. Individuals in the countries and regions who participated in the workshops have testified to the benefits their attendance brings to their future careers and research. Such issues are important: this is how we build indigenous infrastructure and develop a global community of participants. The basic space science workshops for developing countries have been conducted over the past seven years; they have proved very successful both in promoting an

infrastructure and interest in developing countries for space science and in leading to specific space science projects for developing country participation. A task force could examine how to continue them and consider their efficacy and cost, as well as the possibility of additional space agency funding to continue them.

VI. THE ROLE OF NON-GOVERNMENTAL ORGANIZATIONS AS A CATALYST

23. While the main work of space development must come of course from national and international space agencies, non-governmental organizations can play an important catalytic role in partnership with governmental organizations in bringing together needs and capabilities from different sectors of society. Operating with less formality and constraints, and with more focused agendas, non-governmental organizations can serve as both advocates and team-builders for international cooperation, with both working scientists and the general public. Certainly, TPS has played such a role in its Mars programmes and in other planetary missions, but the real focus here is to suggest that non-governmental organizations should serve as catalysts in education and public information. They can help bring together the powerful and considerable materials produced in ESA, the Indian Space Research Organization (ISRO), NASA, the National Space Development Agency (NASDA) of Japan, the Russian Academy of Sciences, the Russian Space Agency (RSA), and many other space agencies, the educational resources of international organizations such as the Committee on Space Research (COSPAR), the International Astronautical Federation (IAF), IAU, the International Council of Scientific Unions (ICSU) and the United Nations system, the scientific professional organizations and the larger public community of students and interested adults, educators and organizations throughout the world who want to participate and want to receive the benefits of space science and exploration. Possible activities that could be undertaken by non-governmental organizations in partnership with space agencies and the United Nations are described in sections VII and VIII below.

VII. EDUCATIONAL MATERIALS AND CURRICULA

24. The United Nations is effective in distributing information, and providing communications for scientists and educators in developing countries who often do not have access to the products produced by the space agencies and aerospace educational organizations. More and more, ESA, NASA and others are turning to the Internet, and in particular the World Wide Web, for their outreach, as they are forced to reduce personnel, material, printing and mailing costs in their programmes. The Web is not really worldwide, however, and Internet access is extremely limited in developing countries. Supplementary programmes are therefore needed to make use of the existing material.

25. In addition to what individual organizations can do, a focused and coordinated programme is needed to leverage individual efforts into truly global ones. There are many outstanding publications and materials available in the educational community and from the space agencies. Help and financial resources are needed in translating and packaging them, for mailing and other distribution. This could be done at relatively low cost. Distribution in such a programme should be proportional to the population in the regions of the world and limited to developing countries in need. It is suggested that no organization contributing material be accepted unless it pay some of the costs of reproduction for global dissemination. Anything that can be done with the exciting materials from the space sciences will be a help in increasing education and awareness. In turn such an overall gain in scientific and technical literacy would contribute to economic and quality of life development in the world.

VIII. SPECIFIC PROJECTS AND TECHNICAL CONTRIBUTIONS

26. A number of specific follow-up projects have included technical involvement of developing countries in basic space science. Of particular interest to the United Nations are the projects being implemented in follow-up to the workshops on basic space science mentioned in section V above:

(a) The Mars drill study in Egypt, with the cooperation of the Russian Federation and TPS;

(b) The refurbishment of the Kottamia observatory in Egypt;

(c) Development of a telescope facility in Sri Lanka;

(d) A galactic emission map project, using a radio telescope, in Colombia;

(e) An astronomical observatory in Honduras;

(f) Publication and distribution of a space science and planetary exploration newsletter in Africa.

27. In addition there are now satellites being developed in countries not hitherto among the space-faring nations, Argentina, Brazil, Indonesia, Israel, Mexico, the Republic of Korea and Thailand, to mention a few. International programmes among Latin American, Arab and Asian companies are also developing satellites. China and India have long had an active space programme and space science capability. There are astronomy projects and programmes and instrument and science participation can be expected in many countries.

28. Some particular projects in space science that can be cited are:

(a) Argentina being the only country in the world to provide government support to the radio astronomical search for extraterrestrial intelligence (with operational support to the META II project installed there by TPS.

(b) Participation by China in the ESA Cluster mission;

(c) Experiments in X-ray and gamma-ray astronomy conducted by India on satellites of the stretched Rohini satellite series (SROSS) and the Indian remote sensing satellite (IRS) series, its participation in the gamma-ray telescope of the Russian Federation and its development of a multi-wavelength observatory to be launched on the polar satellite launch vehicle (PSLV) from India;

(d) Satellite Argentino Científico (SAC) satellite development by Argentina, including the building of an X-ray spectrometer;

(e) Satellite de México (SATEX) spacecraft development by Mexico and the Universidad Autónoma de México Satellite (UNAMSAT) now successfully operating in Earth orbit.

29. Such projects enrich the space sciences and enable new ideas to be brought into circulation. In some cases, with the building of satellites or spacecraft components, they permit costs by one country to be decreased because of participation by others. In the long run that goal should be more and more attainable.

IX. MICROGRAVITY RESEARCH AND THE INTERNATIONAL SPACE STATION

30. The international space station will provide physical and environmental conditions that are not available in the same kind or to the same extent on Earth. One of the most important factors will be weightlessness or, to be physically more correct, reduced gravity, which has come to be known as "microgravity".

31. Gravity is one of the fundamental forces in physics, but not of course the only one that affects physical and chemical processes. The classic procedure for investigating unknown phenomena is to create laboratory conditions in which the various factors influencing a process are separated so that their effect can be studied in isolation. While

it is not impossible to exclude the effect of gravity on Earth, it is difficult and only possible for a short duration. In space, it becomes possible to achieve a reduction of gravity over a very much longer period.

32. In the field of life sciences there are proposals for research projects on the international space station that focus on physiological and biological processes. In this area, the station will undoubtedly act as a major springboard for scientific progress, since it will make it possible to subject experiments to space conditions over a very long period, as well as to provide sufficient experimental opportunities for physiological research in the crew members themselves.

33. In physics, new aspects of materials processing in space and of fluid physics occupy the foreground. It is expected that basic research on the international space station will be able to provide practical help for applications on Earth. Almost free of the influence of gravity, many processes important for modern technology can be studied and understood better. A good example are processes involving phase transitions, which on Earth play an important role in all combustion processes and hence in the production of energy and high-quality materials. The fuller knowledge that can be gained in space because of reduced gravity can make a decisive contribution back on Earth in understanding and controlling the Earth-bound processes better.

34. Another example involves the growing of protein crystals. That does not mean initiating mass production of particular protein crystals on the international space station, but growing and investigating particular crystals in space can help widen the theoretical and practical knowledge and in turn make it possible to master or improve the corresponding crystal-growing processes on Earth.

35. There are, in physics, other proposals for using the station for experiments in fundamental physics, for example, for experiments on how dust, aerosols and plasma particles behave in conditions of weightlessness.

36. In the field of basic space science, one of the first concrete research projects that ESA, for example, will install on the international space station will be devoted to the improvement of atomic clocks. The atomic clock project is called the atomic clock ensemble in space (ACES).

37. The core of the ACES project, developed by CNES, is a laser-cooled caesium atomic clock called "Pharao", which makes use of the conditions of microgravity on board the international space station to reach unprecedented precision not achievable on Earth. In fact, a cold atomic clock will work more accurately under weightlessness on the space station than under gravity on Earth. This is related to the principle of "atomic fountain" used in the clock. Under the conditions of microgravity on the station, the cold atom cloud traverses the microwave cavity at a slower speed than on Earth. This makes it possible to increase the interaction time between the caesium atoms and the microwave field to 5 to 10 seconds, which in turn reduces the atomic resonance line width. The result would be an improvement of the frequency stability and accuracy of the atomic clock by a factor of 100 over conventional devices on Earth.

38. The operation of the laser-cooled caesium atomic clock Pharao on the international space station opens opportunities in various fields of fundamental research and application fields. The ultra-precise measurement of time will also make possible relativistic measurements and tests, applications in atmospheric physics and geodesy, navigation and advanced telecommunications.

X. APPRAISAL

39. There are four main reasons why humanity is interested in the study of basic space science:

(a) Because the knowledge of phenomena elsewhere in the universe can be of benefit in addressing some of the problems on Earth;

(b) Because basic space science has deep roots in virtually every human culture;

(c) Because it helps to understand man's place in the vast scale of the universe;

(d) Because it teaches man about his origins and evolution.

40. The study of basic space science and the benefits derived from it are critical to humanity's future well-being:

(a) Because basic space science is a fundamental element of education;

(b) Because it facilitates international cooperation;

(c) Because it leads to technological developments;

(d) Because it encourages young scientists and engineers;

(e) Because it develops a vision for the future.